Draft Summary

Workshop Summary
**National Earthquake Prediction Evaluation Council (NEPEC)**
Friday, May 18, 2007
Portland State Office Building, Portland, Oregon
And
Saturday, May 19, 2007
Doubletree Hotel, Lloyd Center, Portland, Oregon

**May 18, 2007 – Open Meeting**

**Purpose:** The one-day workshop was convened to present an opportunity for NEPEC members to discuss with a panel of scientific experts the evidence for and nature of episodic nonvolcanic tremor and aseismic creep events and their possible relation to seismic slip on the Cascadia subduction interface; and to discuss with a panel of experts in emergency management and communication how the aseismic slip events and other earthquake-related phenomena in Cascadia should be communicated to government officials and to the public.

**Attending:**

**NEPEC Members:**
Dr. James Dieterich, University of California, Riverside (Chair)
Dr. David Applegate, USGS, Reston (Co-chair)
Dr. Göran Ekström, Columbia University
Dr. William Ellsworth, USGS, Menlo Park, California
Dr. David Jackson, University of California, Los Angeles
Dr. Bruce Shaw, Columbia University
Dr. Robert Wesson, USGS Emeritus, Golden
Dr. Mary Lou Zoback, USGS, Menlo Park
Dr. Michael Blanpied, USGS, Reston (Executive Secretary)

**Workshop Organizers:**
Dr. Evelyn Roeloffs, USGS, Vancouver, Washington
Dr. Vicki McConnell, Oregon State Geologist, Department of Geology and Mineral Industries (DOGAMI)

**Invited Speakers:**
Dr. Richard Allen, University of California, Berkeley
Dr. Lorinda Dengler, Humboldt State University
Mr. Tom Manning, Tillamook County Emergency Management
Dr. Stephane Mazzotti, Geological Survey of Canada
Dr. Tim Melbourne, Central Washington University
Dr. Mike Reichle, California Geological Survey and CEPEC Vice-Chair
Dr. Garry Rogers, Geological Survey of Canada
Dr. David Schmidt, University of Oregon
Dr. John Vidale, University of Washington
Dr. David Wald, USGS, Golden
Mr. Jay Wilson, Oregon Emergency Management

**Summary:**

*First Panel: Scientific understanding of Episodic Tremor and Creep (ETS) and megathrust earthquakes (Moderator: Evelyn Roeloffs, USGS)*

Following introductory remarks by host Vicki McConnell and NEPEC Chair Jim Dieterich, NEPEC received scientific briefings on the nature of episodic tremor and slow slip (ETS) as observed in the Pacific Northwest (PNW) and elsewhere, and current understanding of the location, nature and origin of ETS phenomena and their relationship to great earthquake cycles on the Cascadia subduction interface.

Stephane Mazzotti (GSC) summarized observations of episodic tremor located in PNW seismic data, and episodes of slow slip detected with GPS. These phenomena are clearly linked, with repeating cycles of ETS activity seen in "segments" along the PNW coast, each segment displaying a distinct recurrence interval of between 11 and 14 months. Data beneath Oregon and southern Washington is more sparse, and periodic behavior and segmentation are less clear. Locations of ETS phenomena are only roughly located relative to the subduction interface and the boundary between inferred locked and creeping behavior of that interface. Nonetheless, Mazzotti and colleagues Garry Rogers and Herb Dregert have used a simple model of stress loading to calculate an increase in conditional probability of subduction rupture during the slow creep events. They estimate a probability gain of about 10 during the two weeks of peak ETS activity. In discussion, several sources of uncertainty in the probability calculation were explored, both in the choice of model and in the model parameters.

David Schmidt (U. Oregon) showed a detailed strain inversion analsis of GPS data for the 2007 strain event beneath Puget Sound. The inversion demonstrated that strain release was continuous along strike and occurred within a confined patch. Although aseismic, the equivalent moment magnitude of the slip event was about 6.8. Richard Allen (Berkeley) reviewed the history of 22 ETS events recorded along the entire PNW coast, showing that the could be separated into three zones that appear correlated with inferred fault asperities and forearc basins, and seven distinct segments, each with repeating episodes. Taken together, the boundary produces a slow slip event every 3.5 months on average. Tim Melbourne (Central Washington U) linked the prior talks by showing detailed GPS inversions for slip in 13 individual events, each with a distinct spatial distribution of slip falling largely within the segments identified by both seismic and geodetic data. Melbourne closed by describing the remarkable increase in density of geodetic instruments in Washington and northern Oregon, through installation of the Plate Boundary Observatory (PBO) and other means, which will permit even more detailed examination of ETS in the near future.

John Vidale (U Washington) raised a number of scientific questions about ETS that may be addressed through improved geodetic and seismic recordings from network installations underway or planned. The relationship of ETS to the subduction interface and its locking depth can be explored through more precise and thorough analysis of tremor, for example by an automatic procedure developed by Ken Creager (also at UW). Vidale also advocated the use of world-wide observations to seek systematic features of ETS, for example the correlation of ETS

with subduction locking depth, Gutenburg-Richter distributions of magnitude, and moment scaling. Evelyn Roeloffs (USGS) described borehole strainmeters being installed as a component of PBO. The history of work with strainmeters and strainmeter data since the 1980's demonstrates that these instruments have far better time resolution and strain precision than GPS, but that the analysis and interpretation of data is more difficult due to complex interactions of the instrument and its surrounding borehole, and the poroelastic behavior of the country rock. Nonetheless, the accumulating library of strainmeter data should help in the analysis of ETS.

To cap off the suite of technical talks, Bill Ellsworth (USGS) summarized the strategy employed by Japan to forecast the M~8 subduction earthquake expected to strike the Tokai region and cause great damage to the Tokyo metropolitan area. He showed figures supplied by Mitsuyuki Hoshiba of the Japan Meteorological Agency (JMA). JMA uses a structured program of borehole strain monitoring and seismic tremor monitoring intended to detect precursory slip at the base of the locked zone while also distinguishing strain anomalies unrelated to the plate boundary. ETS has been observed along >300km of the plate boundary beneath southern Honshu and northern Shikoku. When anomalous strain events are detected in data, the likely source region (determined through modeling) is compared to the Tokai region, and further compared to the source of coincident tremor; the strain event is rejected as a precursor if it lies far from Tokai and associated with tremor, as this is a commonplace occurrence.

*Second Panel: Emergency response and communications (Moderator: Vicki McConnell, DOGAMI)*

Lori Dengler (Humbolt State U) began the afternoon session with a survey of newspaper stories and information publications that have explained earthquake and tsunami hazards to residents living near the Cascadia coast. She showed results from questionaires dated 1993 to 2006, which demonstrate a steady increase in awareness of hazards and proper mitigation actions, and also an awareness that responsibility for personal safety lies primarily with those in harm's way, with government in a supporting role. However, the same questionaires show little progress in taking concrete steps to prepare.

Garry Rogers explained steps taken by the Canadian Geological Survey (GSC) to communicate to the media and the public about ETS and the threat of great subduction earthquakes. GSC forecast the 2005 and 2007 ETS episodes beneath Victoria Island based on the regularity of six previous episodes. At the onset of each event Rogers and others briefed emergency organizations and GSC management, put information on the GSC web site, and issued a "research note" press release including the conclusion that large-earthquake probability is enhanced by ten times during the ETS episode. The latter were picked up by news media, which printed many stories. In 2007 some news stories took on a more alarmist tone than anticipated and intended by GSC. Rogers concluded by offering possible ways to convey to the public the message that earthquake probability remains low (in an absolute sense) even if elevated above the background level.

Jay Wilson (Oregon Emergency Management) offered an emergency manager's view on what information is needed to guide appropriate government response during times of increased concern. If there is clear and compelling risk of an impending great earthquake and tsunami (such as a Warning from the Pacific Tsunami Warning Center), it is straightforward for the State

to call for immediate evacuation of low-lying coastal areas. More problematic are other situations (such as a potential foreshock or an unusually sustained slow slip event) that raise concern but for which the probability of a great earthquake is uncertain and likely low. Wilson called for dialog between the science and emergency management communities to build a consensus on terminalogy to describe observed activity, protocols for communicating the scientists' interpretation and its uncertainty, and policy for when to advise the public that risk appears to be elevated. He also urged scientists to identify needed instrumentation to increase understanding of earthquake processes in Cascadia.

Tom Manning of the Tillamook County, Oregon, Department of Emergency Management continued this theme, describing actions taken by the County to prepare for earthquake, tsunami and landslide hazards. Helpful tools include hazard maps, tsunami innundation maps, coordination with various public and private organizations, and the experience from past hazard events. The County has implemented a tsunami warning notification system that communicates warning across a broad spectrum of methods to the government and those in harm's way. The County builds public education by repeating a set of straightforward messages about the nature of tsunami waves and how to avoid them.

Mike Reichle of the California Geological Survey (CGS) described California's protocols for the review of earthquake predictions and situations of concern, and the relationship between CGS, the California Office of Emergency Services (OES), which has responsibility for public notificiation, and the California Earthquake Prediction Evaluation Council (CEPEC), an expert body that advises OES on earthquake prediction matters. Procedures for review, communication and public notification are dictated by the California Earthquake Advisory Plan and Earthquake Prediction Response Plan. CEPEC has written advisories following various M>5 earthquakes, and has evaluated several earthquake predictions proposed by individuals; however, the Parkfield earthquake prediction stands alone in being validated by CEPEC. In response to that validation, OES developed a plan describing steps to be taken in response to possible Parkfield precursors.

David Wald (USGS) concluded the session by describing the range of information products available from the National Earthquake Information Center (NEIC) following large earthquakes near the Cascadia coastline.

*Discussion*

NEPEC members engaged in conversation with the panel members throughout the day. Key points emphasized by Dieterich and other members were that the science of ETS is young and evolving, that it is highly uncertain how ETS events relate to the subduction interface and subduction earthquake cycle, and that it is unclear how to properly calculate the effect of ETS on large-earthquake probability. The sense of the committee was that the slip events likely increase probability of great earthquakes; however, it was pointed out that there have been at least 100 ETS episodes recorded in Japan and the Pacific Northwest, none of them associated with a great earthquake. There was agreement in discussion that increased communication and coordination between scientists and response officials was important.

*Morning discussion*

The NEPEC met briefly on the morning of May 19 to continue discussions. They were joined by Mike Reichle and Evelyn Roeloffs. Key points emerged from that discussion: (1) ETS events appear to represent added increments of load to the locked portion of the subduction interface, so it is important to increase understanding of their possible role in promoting or triggering future large events. (2) Because the events occur frequently and have not been observed to trigger great earthquakes, ETS events are of limited value, in and of themselves, in prediction. (3) An unusual deviation from the observed pattern of ETS, such as a large or longer strain event, would be of considerable concern and warrant close inspection. (4) The Pacific Geoscience Center of the GSC has played a leading role in organizing and coordinating the study of ETS and related phenomena, and deserve emuation by the USGS. (5) The USGS should explore means for improving the coordination and focus of its studies on the temporal variations of tectonic activity within the subduction zone, including ETS and any related phenomena, with the aim of developing a means of assessing this behavior and flagging any anomalies or changes that might occur. Possible activities might include websites for the exchange of data and information, periodic coordination meetings and/or topical research meetings, and the designation of an USGS staff member to promote coordination on this topic.